APPENDIX II

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Tetsuya KAMIHARA
Title:	FUEL CELL SYSTEM
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DECLARATION OF YOJI ITO

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

I, Yoji Ito, a citizen of Japan, declare and state that:

1. I am fluent in the written English Language and the written Japanese language.

2. Exhibit I presents an accurate English language translation of the Japanese language document of Exhibit II.

3. I declare that all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the

United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Date *Feb. 2/2009* *Yoji Ito*

Yoji Ito

EXHIBIT I

SHEET FOR PRODUCING SPECIFICATION DRAFT

[TITLE OF THE INVENTION] FUEL CELL SYSTEM

[CLAIMS]

[Claim 1] A fuel cell system comprising: a fuel cell in which a fuel electrode and an oxidant electrode are located to be opposed to each other so as to interpose an electrolyte membrane therebetween; gas supply means for supplying oxidant gas and fuel gas to the fuel cell; recirculation means for recirculating unused fuel gas from the fuel cell back to a fuel cell inlet; a passage for discharging the fuel gas from a recirculation passage connecting between a fuel discharge passage and a fuel supply passage of the fuel cell; a variable throttle valve provided in the above discharge passage; and means for directly or indirectly detecting an opening of the variable throttle valve, wherein the opening of the variable throttle valve is controlled so that a nitrogen concentration in the hydrogen system is kept constant.

[Claim 2] The fuel cell system according to claim 1, further comprising: means for directly or indirectly detecting a flow amount of the fuel gas passing through the variable throttle valve, wherein the valve opening of the variable throttle valve is reduced if the flow amount of the fuel gas passing through the variable throttle valve is more than a predetermined value set in accordance with operation conditions and the valve opening of the variable throttle valve, and increases the valve opening of the variable throttle valve if the flow amount of the fuel gas passing through the variable throttle valve is less than the predetermined value.

[Claim 3] The fuel cell system according to claim 2, wherein the predetermined value is set larger as the valve opening of the variable throttle valve becomes the larger.

[Claim 4] The fuel cell system according to claim 2, further comprising: means for detecting a temperature of the fuel gas passing through the variable throttle valve, wherein the predetermined value is set lower as the temperature of the fuel gas rises.

[Claim 5] The fuel cell system according to claim 2, further comprising: means for detecting pressure of the fuel gas in the supply system, wherein the predetermined value is set lower as the pressure of the fuel gas drops.

[Claim 6] The fuel cell system according to claim 1, further comprising: means for directly or indirectly detecting a fuel gas supply amount to the fuel cell system; and mean for detecting directly or indirectly a consumption amount other than an amount discharged from the variable throttle valve among the fuel gas consumed in the fuel cell system, wherein a flow amount of the fuel gas passing through the variable throttle valve is obtained from a difference between the supply amount and the consumption amount.

[Claim7] The fuel cell system according to claim 6, further comprising: an ejector as recirculation means of the fuel gas; and ; and means for detecting a supply pressure of the fuel gas supplied to the ejector or the supply pressure and an ejector discharge pressure, wherein the supply amount of the fuel gas to the fuel cell system is calculated based on the fuel gas supply pressure or the supply pressure and the discharge pressure.

[Claim8] The fuel cell system according to claim 7, further comprising: means for detecting a temperature of the fuel gas upstream of the ejector, wherein the supply amount of the fuel gas to the fuel cell system is calculated based on the fuel gas supply pressure or the supply pressure and the discharge pressure, and the temperature of the fuel gas upstream of the ejector.

[Claim 9] The fuel cell system according to claim 6, further comprising: a variable throttle valve provided in a passage supplying a fuel gas to the fuel cell system; means for directly or indirectly detecting a valve opening of the variable throttle valve; and means for detecting a pressure of the fuel gas upstream of the variable throttle valve or upstream and downstream pressures of the variable throttle valve, wherein the supply amount of the fuel gas to the fuel cell system is calculated based on the valve opening of the variable throttle valve, and the pressure of the fuel gas upstream or the upstream and downstream pressures of the variable throttle valve.

[Claim 10] The fuel cell system according to claim 9, further comprising: means for detecting a temperature of the fuel gas upstream of the variable throttle valve, wherein the supply amount of the fuel gas to the fuel cell system is calculated based on the valve opening of the variable throttle valve, the pressure of the fuel gas upstream or the upstream and downstream pressures of the variable throttle valve, and the temperature of the fuel gas upstream of the variable throttle valve.

[Claim 11] The fuel cell system according to claim 6, further comprising: means for detecting an output current of the fuel cell, wherein the consumption amount of the fuel gas is calculated based on the output current.

[Claim 12] The fuel cell system according to claim 6, further comprising: means for detecting an output current of the fuel cell; means for detecting pressure of the fuel gas upstream or downstream of the fuel cell, and means for detecting a time change of the pressure of the fuel gas, wherein the consumption amount of the fuel gas is calculated based the output current and the time change of the pressure of the fuel gas.

[BACKGROUND ART]

For example, Japanese Patent Application Laid-Open No. 2001-266922 discloses a fuel cell system.

In Polymer Electrolyte Fuel Cell system using hydrogen gas as fuel for a fuel cell stack thereof, hydrogen gas unused at the fuel cell stack is returned to a supply line thereof to be recirculated in a closed loop hydrogen system. Recirculation of the hydrogen gas thereof provides a hydrogen supply to the fuel cell stack at a rate exceeding consumption rate thereof, stabilizing power generation by the fuel cell stack.

In the present conventional example, unused hydrogen is recirculated by use of an ejector provided on a supply line to the fuel cell.

[PROBLEM TO BE SOLVED BY THE INVENTION]

In the fuel cell system described above, when air is used as an oxidant, nitrogen contained in the air is transported due to diffusion from cathode flow channels through polymer electrolyte membranes to anode flow channels of the fuel cell stack, and a nitrogen concentration increases in the hydrogen gas of the hydrogen system.

When the nitrogen concentration in the hydrogen gas increases, a hydrogen partial pressure thereof is lowered, resulting in a drop in power generation efficiency of the fuel cell system. An amount of hydrogen recirculated through the ejector is also lowered, adversely affecting the maintenance of the stable power generation of the system.

Provision of a variable throttle valve for purging the nitrogen in the hydrogen system, which is to be periodically opened to discharge the nitrogen containing hydrogen gas to the atmosphere, may be a measure for this problem. However, when the variable throttle valve is opened, the hydrogen and the nitrogen in the hydrogen gas are discharged together. If the

variable throttle valve continues to be opened, the performance of the fuel cell system drops. An optimal purge method for restricting the efficiency deterioration is not disclosed yet.

The present invention has been made in the light of the problems described above. It is an object of the present invention to improve performance of a fuel cell system, controlling an amount of hydrogen to be discharged out of a hydrogen system, while purging nitrogen transported to the hydrogen system due to diffusion.

[EFFECTOF THE INVENTION]

The present invention is a fuel cell system comprising: a fuel cell in which a fuel electrode and an oxidant electrode are located to be opposed to each other so as to interpose an electrolyte membrane therebetween; gas supply means for supplying oxidant gas and fuel gas to the fuel cell; recirculation means for recirculating unused fuel gas from the fuel cell back to a fuel cell inlet; a passage discharging the fuel gas from a recirculation passage connecting between a fuel discharge passage and a fuel supply passage of the fuel cell; a variable throttle valve provided in the above discharge passage; and means for directly or indirectly detecting an opening of the variable throttle valve. This system has the following features.

According to the invention as defined in claim 1, there is provided means for directly or indirectly detecting a nitrogen concentration in the hydrogen system and the variable throttle valve is controlled so that the nitrogen concentration in the hydrogen system is kept constant. In consequence, a fuel cell system which restricts a discharge hydrogen amount to improve the efficiency can be provided.

According to the invention as defined in claim 2, there is provided the means for directly or indirectly obtain the

passing flow amount of the variable throttle valve, wherein the opening of the variable throttle valve is reduced if the flow amount is more than a predetermined value set in accordance with operation conditions and the valve opening of the variable throttle valve, and the opening of the variable throttle valve is increased if the flow amount is less than the predetermined value. In consequence, a fuel cell system which restricts a discharge hydrogen amount to improve the efficiency can be provided.

According to the invention as defined in claim 3, the predetermined value is set larger as the valve opening of the variable throttle valve becomes larger. In consequence, a fuel cell system which restricts a discharge hydrogen amount to improve the efficiency can be provided.

According to the invention as defined in claim 4, there is provided means for directly or indirectly detecting a gas temperature passing through the variable throttle valve, wherein the predetermined value is set lower as the gas temperature rises. In consequence, a fuel cell system which restricts a discharge hydrogen amount to improve the efficiency can be provided.

According to the invention as defined in claim 5, there is provided means for directly or indirectly detecting a fuel gas pressure in the fuel passage, wherein the predetermined value is set lower as the gas pressure drops. In consequence, a fuel cell system which restricts a discharge hydrogen amount to improve the efficiency can be provided.

According to the invention as defined in claim 6, there are provided means for directly or indirectly detecting a fuel gas supply amount to the fuel cell system and means for directly or indirectly detecting a consumption amount other than the amount discharged from the variable throttle valve among the fuel gas consumed in the fuel cell system, wherein a passing

flow amount of the variable throttle valve is found from a difference between the supply amount and the consumption amount. In consequence, a fuel cell system which restricts a discharge hydrogen amount to improve the efficiency can be provided.

According to the invention as defined in claim 7, there are provided an ejector as the recirculation means of the fuel gas and means for detecting a fuel gas supply pressure or a supply pressure and a discharge pressure thereof, wherein a supply fuel gas flow amount to the fuel cell system is calculated from the fuel gas supply pressure or the fuel gas supply pressure and discharge pressure. In consequence, a fuel cell system which restricts a discharge hydrogen amount to improve the efficiency can be provided.

According to the invention as defined in claim 8, there is provided means for detecting a fuel gas temperature upstream of the ejector, wherein a supply fuel gas flow amount to the fuel cell system is calculated from the fuel gas supply pressure or the fuel gas supply pressure and discharge pressure, and the fuel gas temperature upstream of the ejector. In consequence, a fuel cell system which restricts a discharge hydrogen amount to improve the efficiency can be provided.

According to the invention as defined in claim 9, there are provided a variable throttle valve, means for directly or indirectly detecting an opening of the variable throttle valve, and means for detecting a pressure upstream of the variable throttle valve or pressures upstream and downstream of the variable throttle valve in a passage supplying a fuel gas to the fuel cell system, wherein a supply fuel gas flow amount to the fuel cell system is calculated from the opening of the variable throttle valve, and the pressure upstream of the variable throttle valve or the pressures upstream and downstream of the variable throttle valve. In consequence, a fuel cell system which restricts a discharge hydrogen amount to improve the efficiency can be provided.

According to the invention as defined in claim 10, there is provided means for detecting a fuel gas temperature upstream of the variable throttle valve, wherein a supply fuel gas flow amount to the fuel cell system is calculated from the opening of the variable throttle valve, the pressure upstream of the variable throttle valve or the pressures upstream and downstream of the variable throttle valve, and the fuel gas temperature upstream of the variable throttle valve. In consequence, a fuel cell system which restricts a discharge hydrogen amount to improve the efficiency can be provided.

According to the invention as defined in claim 11, there is provided means for detecting an output current of the fuel cell, wherein the consumption amount of the fuel gas is calculated based on the output current. In consequence, a fuel cell system which restricts a discharge hydrogen amount to improve the efficiency can be provided.

According to the invention as defined in claim 12, there are provided means for detecting an output current of the fuel cell, means for detecting pressure of the fuel gas upstream or downstream of the fuel cell, and means for detecting a time change of the pressure of the fuel gas, wherein the consumption amount of the fuel gas is calculated based the output current and the time change of the pressure of the fuel gas. In consequence, a fuel cell system which restricts a discharge hydrogen amount to improve the efficiency can be provided.

[EMBODIMENT]

Hereinafter, an embodiment of the present invention will be explained with the accompanying drawings.

Fig. 1 shows a fuel cell system of the present invention. Numeral 1 denotes a fuel cell stack where cathode (as oxidant electrode, or air electrode) 1b and anode (as fuel electrode) 1c are provided so as to be parallel to each other with a polymer

electrolyte membrane 1a interposed therebetween. These elements arranged in this manner collectively constitute a fuel cell element. Each fuel cell element is further sandwiched by a pair of separators. The fuel cell stack 1 is constituted of a plurality of these sandwiched elements stacked on each other. The fuel gas is introduced into anode flow channels 1f provided between the anode and the separator, and air as an oxidant is introduced into cathode flow channels 1e provided between the cathode and the separator.

The fuel gas is supplied from the fuel tank 2 to the fuel cell stack 1 via a variable throttle hydrogen pressure regulator 3, in which throttle opening thereof is detected by a sensor. Pressure of the fuel gas supplied to the fuel cell stack 1 is detected by a pressure sensor 4 and is controlled by a controller 100 to be kept within a proper range.

An ejector 6 is provided on a supply line 5 between the regulator 3 and the fuel cell stack 1. To a side-stream port 6a of the ejector 6, a return line 7 from the fuel cell stack 1 is connected. The ejector 6 withdraws unused fuel gas of the fuel cell stack 1 from the return line 7, and pumps it to an inlet of the fuel cell stack 1. The supply line 5, the ejector 6, the anode flow channels of the fuel cell stack 1 and the return line 7 collectively constitute a hydrogen system through which the fuel gas is circulated to thereby enhance electrochemical reaction efficiency in the fuel cell stack 1 and stabilize power generation thereof.

Nitrogen contained in the air is partially transported due to diffusion from the cathode flow channels 1e through the membranes to the anode flow channels, and is thereby introduced into the hydrogen system. The variable throttle valve 8 has therein a sensor for detecting a valve opening degree thereof, and, based on the detected valve opening degree, the controller controls valve opening thereof to maintain a concentration of nitrogen in the hydrogen system within a proper range. A method

for controlling the variable throttle valve 8 will be described later.

It should be noted that the air introduced to the system by the compressor 9 is supplied through the air supply line 10 and is discharged together with the formed water outside of the air system through the variable throttle valve 11 serving as an air system pressure regulator.

A coolant line 12 connects the stack 1, the coolant pump 14 and the radiator 13 in series. The coolant is pumped by the coolant pump 14 to be circulated through the cooling system. After flowing out of the coolant passage in the fuel cell stack 1, coolant flows through the coolant passage 12 to the radiator 13 where the coolant exchanges heat with the atmosphere.

Next, an operation will be explained with reference to a flow chart in Fig. 2.

In Step S1, it is determined at a predetermined point of time whether or not the purged hydrogen flow amount, that is a flow amount of the hydrogen in the nitrogen containing fuel gas which is discharged outside of the system from the variable throttle valve 8, is equal to or more than a predetermined value, or within or more than a predetermined value band having a certain range. A calculation method for the flow amount of the hydrogen will be described later. If the purged hydrogen flow amount is equal to or more than the predetermined value, or within or more than the predetermined value band, the control process proceeds to step S2. If the purged hydrogen flow amount is less than the predetermined value or the predetermined value band, the process proceeds to step S3. In Step S2, the valve opening degree Vo of the variable throttle valve 8 is decreased so as to reduce a discharge amount of the fuel gas. On the other hand, in Step S3, the valve opening degree of the variable throttle valve 8 is increased so as to increase the discharge amount of the fuel gas.

FIG 3 shows a relation between a nitrogen concentration in the hydrogen system and an ejector-circulating hydrogen flow amount, that is, a flow amount of the hydrogen of the fuel gas circulating through the ejector 6, in the first embodiment under a condition where the fuel gas temperature Th2 and fuel gas pressure Ph2 are kept constant. As shown in FIG3, when the nitrogen concentration in the hydrogen system increases and a hydrogen partial pressure of the fuel gas in the system decreases, the ejector-circulating hydrogen flow amount is lowered. This necessitates opening the variable throttle valve 8 for purging nitrogen in the system to lower the nitrogen concentration in the hydrogen system.

Assuming that Qr is the minimum ejector-circulating hydrogen flow amount required for steady operation of the fuel cell stack 1, the nitrogen concentration in the hydrogen system needs to be controlled to be Rn or less, so that the ejector-circulating hydrogen flow amount Qc does not fall below Qr. However, when the variable throttle valve 8 is opened for purging nitrogen in the hydrogen system so as to lower the nitrogen concentration Rn in the fuel gas therein, the hydrogen in the fuel gas is also discharged, adversely affecting the performance of the fuel cell system.

To avoid this problem, it is necessary, to some extent, to decrease the hydrogen concentration in the fuel gas of the hydrogen system and to increase the nitrogen concentration therein. The control of the variable throttle valve 8 for proper adjustment of the valve opening degree thereof provides nitrogen concentration in the hydrogen system stably maintained at Rn and the purged hydrogen flow amount is kept to the requisite minimum.

FIG. 4 shows a relation between the nitrogen concentration in the hydrogen system and the purged hydrogen flow amount through the variable throttle valve 8 under a condition where the valve opening degree of the variable

throttle valve 8 and the fuel gas temperature and fuel gas pressure are kept constant. It is understood that, under this condition, as the nitrogen concentration decreases in the system, the purged hydrogen flow amount increases due to the increased hydrogen partial pressure in the fuel gas.

FIG 5 shows a relation between the valve opening degree Vo of the variable throttle valve 8 and the purged hydrogen flow amount under a condition where the fuel gas temperature Th2 and fuel gas pressure and the nitrogen concentration in the hydrogen system are kept constant. As shown in FIG 5, under this condition, the purged hydrogen flow amount tends to increase as the valve opening degree of the variable throttle valve 8 increases.

FIG 6 shows a relation between fuel gas temperature downstream the fuel cell stack 1 (or the variable throttle valve inlet temperature detected by the temperature sensor 21) and the purged hydrogen flow amount under a condition where the nitrogen concentration in the hydrogen system, the fuel gas pressure and the valve opening degree of the variable throttle valve 8 are kept constant. Since the fuel cell stack 1 is a stack of polymer electrolyte fuel cells, the fuel gas in the hydrogen system is saturated or nearly saturated with water vapor downstream of the fuel cell stack 1 near the variable throttle valve 8. Since the saturated vapor pressure of the fuel gas is elevated as the fuel gas temperature rises, the fuel gas can contain more molecules of water vapor, whereby the average molecular weight thereof is increased. Accordingly, the hydrogen partial pressure in the fuel gas is lowered, and the purged hydrogen flow amount is decreased.

FIG 7 shows a relation between the purged hydrogen flow amount and the fuel gas supply pressure to the fuel cell stack 1 under a condition where the nitrogen concentration, the fuel gas temperature and the valve opening degree of the variable throttle valve 8 are kept constant. As shown in FIG 7, under

this condition, the purged hydrogen flow amount tends to decrease as the fuel gas supply pressure is lowered.

In consequence, when the purged hydrogen flow amount, the purge valve opening, and the temperature of the hydrogen, the pressure are found, the nitrogen concentration in the hydrogen system is found.

Next, a calculation method for the purged hydrogen flow amount will be described.

In the present embodiment, the purged hydrogen flow amount Qph is the remainder obtained from a formula Qph = Qih-Qeh, wherein Qih is a flow amount of the hydrogen supplied to the fuel cell system and Qeh is a flow amount of hydrogen to be consumed without being purged.

First, a method for obtaining the flow amount Qih of the hydrogen supplied to the fuel cell system will be described.

In general, the flow amount of the hydrogen passing through the regulator 3 can be calculated from the pressure and temperature of the fuel gas upstream of the regulator 3, when the regulator 3 is in a choked state where the valve opening degree thereof is small. And when the regulator 3 is in an unchoked state, the flow amount can be calculated from the pressures of the fuel gas upstream and downstream of the regulator 3 and the temperature of the fuel gas upstream thereof.

In this embodiment, the ejector 6 has a choking nozzle inside thereof for a fuel gas supply system. Therefore, the supplied hydrogen flow amount can be calculated by use of the ejector inlet pressure and ejector outlet pressure.

The study is made in regard to a case where a supply temperature of the hydrogen does not change so much. As shown in Fig. 8, a pressure sensor 20 is provided upstream of the

ejector. Since the ejector downstream pressure is substantially equal to the stack inlet hydrogen pressure, the ejector downstream pressure can be detected. In consequence, since the upstream and downstream pressures of the ejector can be detected, the supply hydrogen flow amount to the system can be calculated.

In the case where the temperature of the supplied fuel gas varies in a wide range, the supplied hydrogen flow amount can be, as shown in Fig. 9, calculated more precisely by making a correction for the fuel gas temperature which is detected by the temperature sensor 22 provided in the fuel gas supply system.

Next, a method for obtaining the flow amount of hydrogen to be consumed without being purged will be described.

The amount of hydrogen consumption in the fuel cell stack 1 is proportional to an output current of the fuel cell stack 1, which can be detected by an ammeter (not shown). Therefore, the flow amount of hydrogen to be consumed without being purged can be calculated from the detected output current.

From the aforementioned characteristic, the valve opening degree of the variable throttle valve 8, the purge hydrogen flow amount, the hydrogen pressure, and the hydrogen temperature can be detected by the respective sensors. The purge hydrogen flow amount can be detected in a case where the nitrogen concentration is a predetermined value with the valve opening degree of the variable throttle valve 8, the hydrogen pressure, and the hydrogen temperature. This calculated purge hydrogen flow amount, which is set as a predetermined value in a flow chart in FIG. 2, is compared with the detected hydrogen purge flow amount.

Therefore, the larger the valve opening degree of the variable throttle valve 8 is, the higher the predetermined value is set, and the higher the fuel gas temperature is and the lower

the fuel gas pressure is, the lower the predetermined value is set.

As described above, according to the present invention, the nitrogen concentration in the hydrogen system is controlled to be constant. Accordingly, excessive purge of nitrogen in which hydrogen is wastefully discharged together with the purged nitrogen, is prevented, thus contributing the stabilized power generation of the fuel cell system.

Next, a second embodiment of the present invention will be explained.

FIG 10 is a diagram illustrating a configuration of a fuel cell system according to a second embodiment of the present invention. A pressure sensor 23 is provided to detect pressure of the fuel gas upstream of the regulator 3. The supplied hydrogen flow amount is calculated by use of a regulator inlet pressure and regulator outlet pressure, which have been detected by the pressure sensors 23 and 20 provided upstream and downstream of the regulator 3, respectively.

In FIG 8, elements denoted by the same reference numerals as those in FIG 1 have the same functions.

In this embodiment, given a valve opening degree Vr of the regulator 3 which is detected by the controller 100 controlling the opening/closing of the regulator 3, the supplied hydrogen flow amount Qih can be calculated based on the valve opening degree Vr thereof and the regulator inlet pressure Ph3 and regulator outlet pressure Ph2 similarly to the case of obtaining the same flow amount Qih from the ejector inlet pressure Ph1 and outlet pressure Ph2.

The supplied hydrogen flow amount is calculated only from the regulator inlet pressure when the valve opening degree of the regulator 3 is small enough for the regulator 3 to be in

a choked state. When the regulator inlet pressure is in an unchoked state, the supplied hydrogen flow amount is calculated from the regulator inlet pressure and the regulator outlet pressure. This is the same as in the first embodiment.

In the second embodiment, a temperature sensor 23 is provided in the coolant passage of the fuel cell stack 1 to detect a coolant temperature. Since the fuel gas and the coolant exchange heat in the fuel cell stack 1, the coolant temperature and the fuel gas temperature are approximately equal to each other, and it is possible to use the coolant temperature as the fuel gas temperature estimate the fuel gas temperature from. Moreover, the coolant is in the form of liquid, which provides better responsiveness for temperature measurement than gas. Even if the coolant temperature varies due to the rapidly changing load on the fuel cell system, the coolant still provides more accurate temperature measurement than a fuel gas.

Similarly to the first embodiment, a temperature sensor is provided in the fuel gas supply system upstream of the regulator 3 to detect fuel gas temperature thereat. For varying temperature of the supplied fuel gas, correction can be made for more accurate supplied hydrogen flow amount based on the detected fuel gas temperature.

Next, a third embodiment of the present invention will be described.

The third embodiment is different from the first or second embodiment in that an improvement is made for the calculation of the amount of hydrogen consumption by the electrical power generation of the fuel cell stack 1.

A fuel cell system for a vehicle is required to cope with the rapidly changing load on the system S and to be capable of adjusting the output of the fuel cell stack 1 depending on the changing load. For variable output thereof, the pressure of the

fuel gas supplied to the fuel cell stack 1 is controlled. In order to increase the supply pressure of the fuel gas, it is necessary to supply hydrogen to the hydrogen system at an amount more than a value that is calculated from the rate of hydrogen consumption by the electrical power generation of the fuel cell stack 1. On the other hand, in order to decrease the supply pressure of the fuel gas, an amount of hydrogen supplied to the system is reduced to less than the value. In the case of taking only the amount of hydrogen consumption by the electrical power generation of the fuel cell stack 1 into consideration, it is impossible to calculate accurately the purged hydrogen flow amount in a time of transition while the fuel gas pressure is being increased or decreased.

Here, while the flow amount of hydrogen supplied to the hydrogen system is being changed in order to increase and decrease the fuel gas pressure in the system, a difference between the supplied hydrogen flow amount and the amount Qe of hydrogen consumption by the electrical power generation of the fuel cell stack 1 is proportional to a pressure variation rate or pressure difference DP of the changing fuel gas pressure, that is a difference between a target fuel gas pressure determined based on a required output of the fuel cell stack 1 and a fuel gas pressure at present. Specifically, the supplied hydrogen flow amount Qih is represented by: $Qih = Qe + C \times DP$ where C is a constant to be determined depending on a capacity of the hydrogen system of the fuel cell system S. The fuel gas pressure is detected by the pressure sensor 4. Therefore, by provision of a unit for obtaining the pressure difference DP of the fuel gas pressure, the supplied hydrogen flow amount Qih in a time of transition when the fuel gas pressure is being changed can be calculated based on the pressure difference DP.

According to the third embodiment, the supplied hydrogen flow amount Qih can be calculated accurately even if the fuel gas pressure is being changed. Thus, the purged hydrogen flow amount can be calculated more accurately, contributing to

precise control of the nitrogen concentration in the hydrogen system.

Although the ejector 6 is used for circulating the fuel gas in the first to third embodiments, the present invention can be applied even if the fuel gas is circulated by use of, for example, a pump or a blower.

Even in the case of using the pump or the blower, similarly to the case of using the ejector 6, an increase of the nitrogen concentration in the hydrogen circulation system results in a drop of the hydrogen partial pressure therein, which necessitates an increase of the supplied hydrogen flow amount Qih. Even in such a case, similarly to the second embodiment, adjustment of the supplied hydrogen flow amount Qih is made by calculation based on the valve opening degree of the regulator 3, the regulator inlet pressure and the regulator outlet pressure, which gives the optimum timing to close the variable throttle valve.

Moreover, the sensors for detecting the fuel gas pressure may be provided not upstream of the fuel cell stack 1 but downstream thereof. Especially for the case that a pressure loss of the fuel gas of the fuel cell stack 1 is large, detection of the fuel gas pressure upstream of the stack 1 provides more precise control.

[BRIEF DESCRIPTION OF DRAWINGS]

FIG 1 is a diagram illustrating a basic configuration of the present invention.

FIG 2 is a flowchart showing a basic control of the present invention.

FIG 3 is a graph showing a relation between a nitrogen concentration in a hydrogen system and an ejector-circulating hydrogen flow amount.

FIG 4 is a graph showing a relation between the nitrogen concentration in the hydrogen system and a purged hydrogen flow amount.

FIG. 5 is a graph showing a relation between the valve opening degree of the variable throttle valve and the purged hydrogen flow amount.

FIG 6 is a graph showing a relation between the stack outlet hydrogen temperature and the purged hydrogen flow amount.

FIG 7 is a graph showing a relation between the stack inlet hydrogen pressure and the purged hydrogen flow amount.

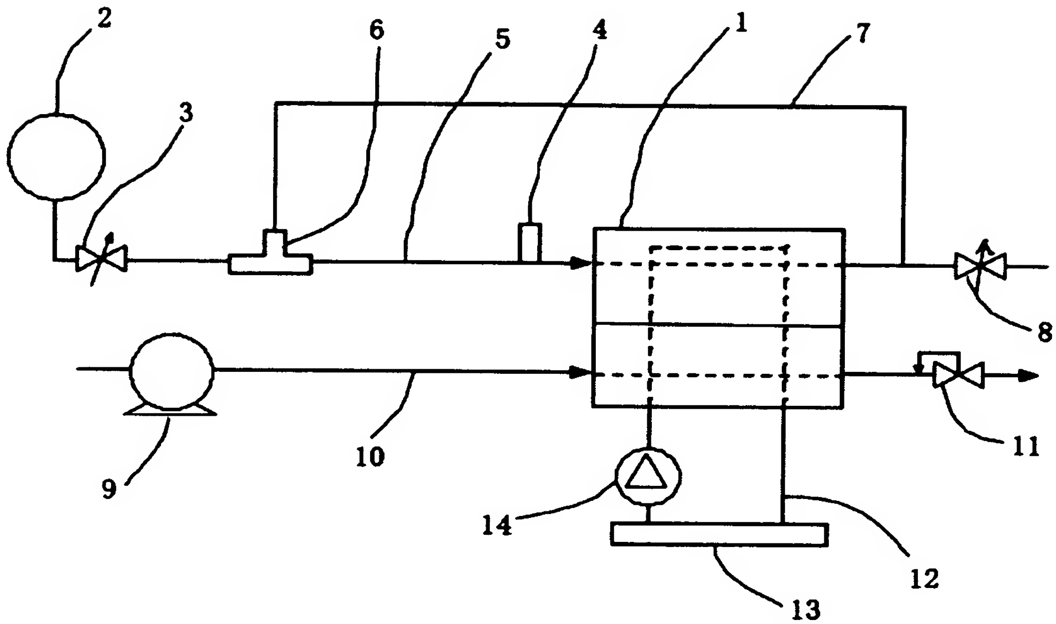
FIG 8 is a diagram illustrating a configuration in a first embodiment of the present invention.

FIG 9 is a diagram illustrating a configuration in a first embodiment of the present invention.

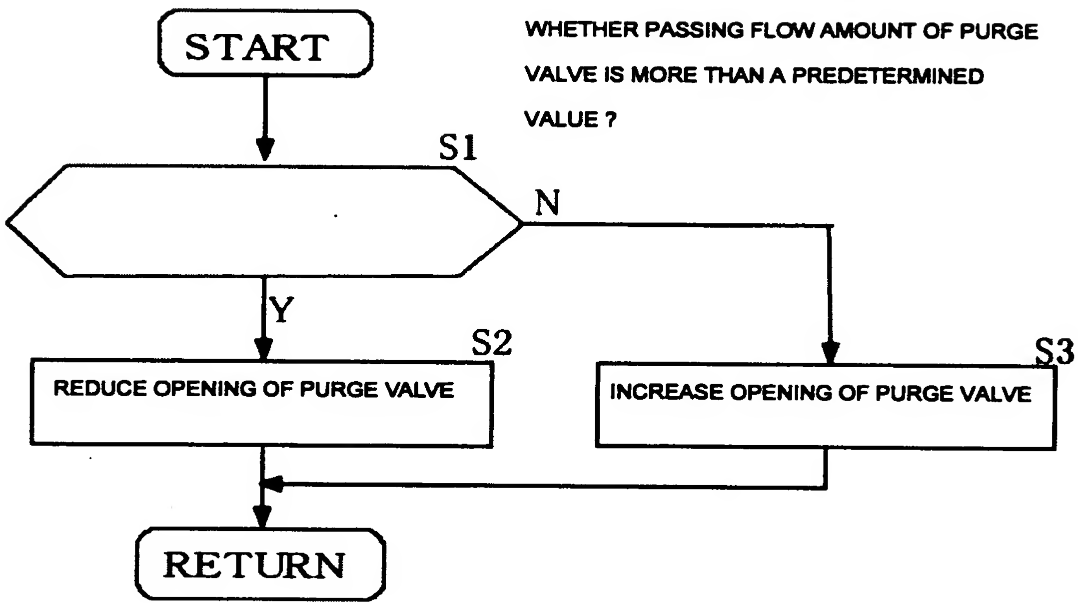
FIG 10 is a diagram illustrating a configuration in a second embodiment of the present invention.

【FIG 1.】

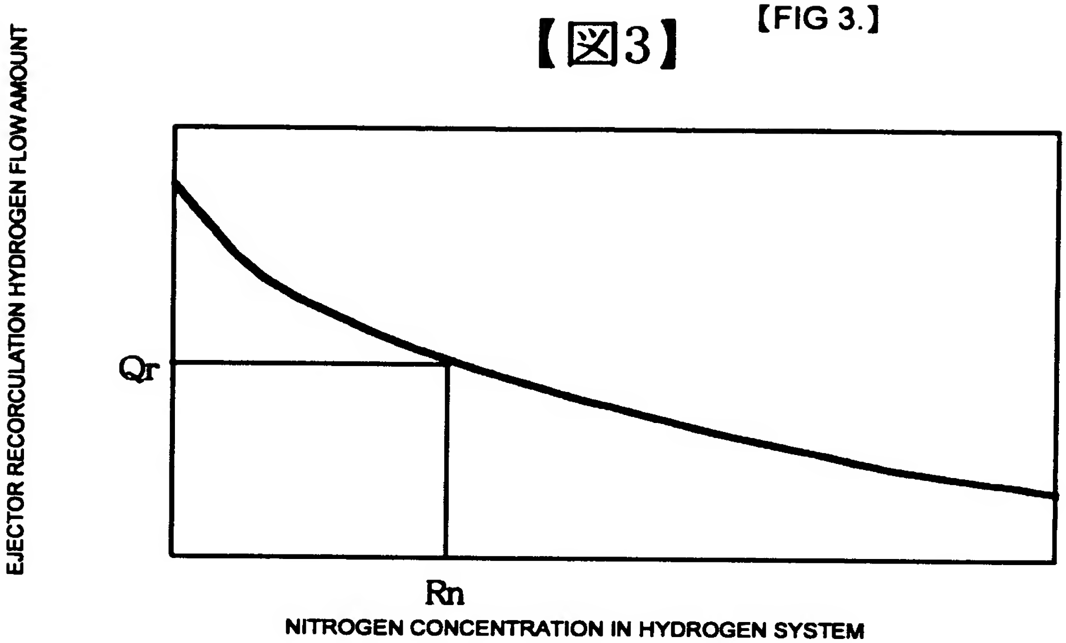
【図1】



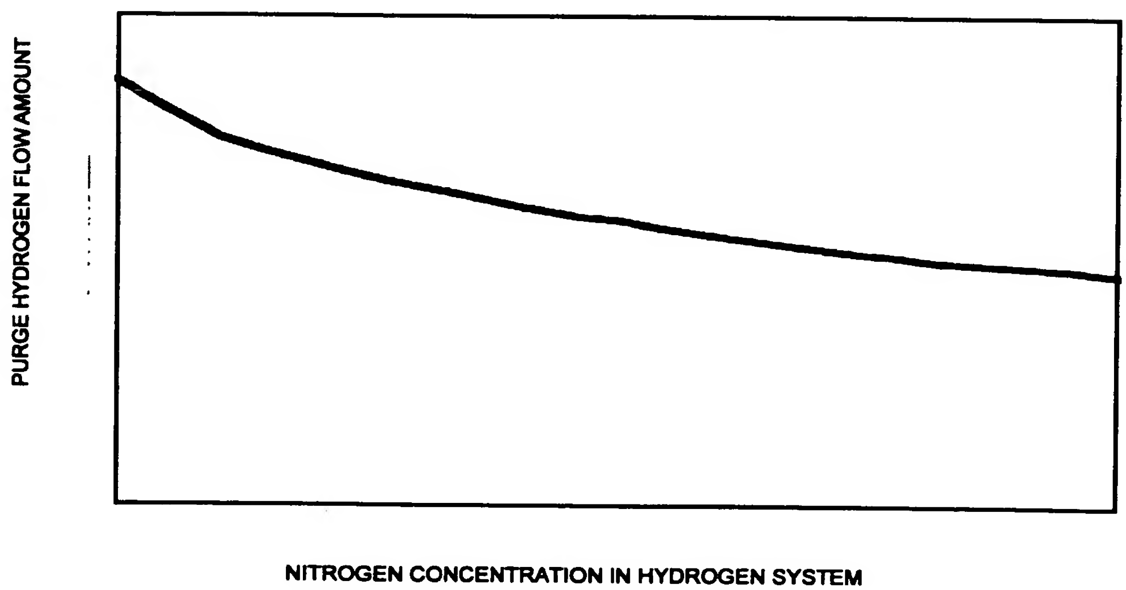
【図2】 【FIG 2.】


START
WHETHER PASSING FLOW AMOUNT OF PURGE VALVE IS MORE THAN A PREDETERMINED VALUE ?
S1
N
Y
S2
REDUCE OPENING OF PURGE VALVE
S3
INCREASE OPENING OF PURGE VALVE
RETURN

【図3】 【FIG 3.】

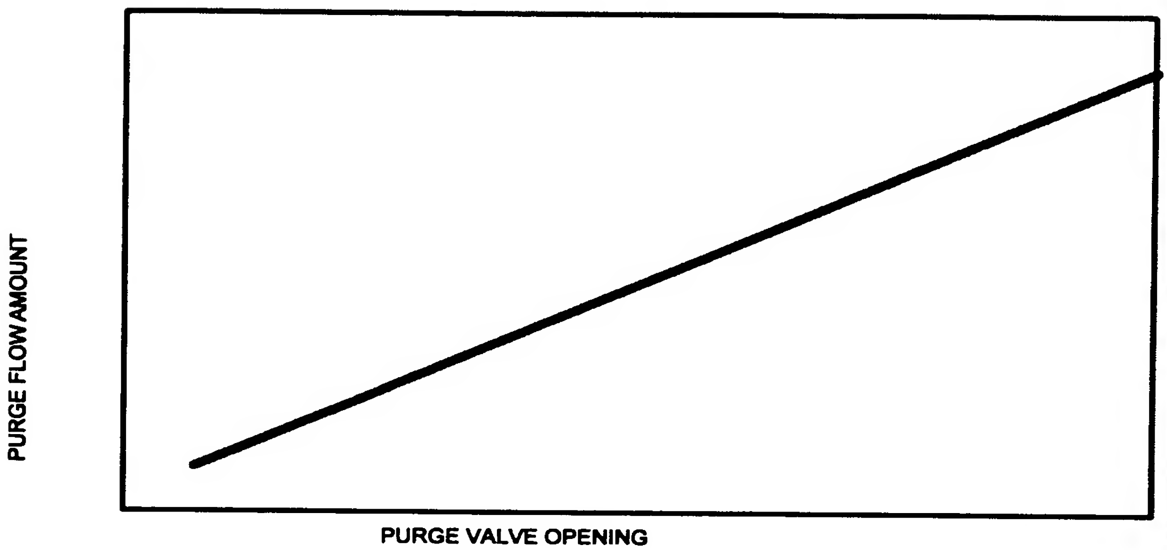


【図4】 【FIG 4.】



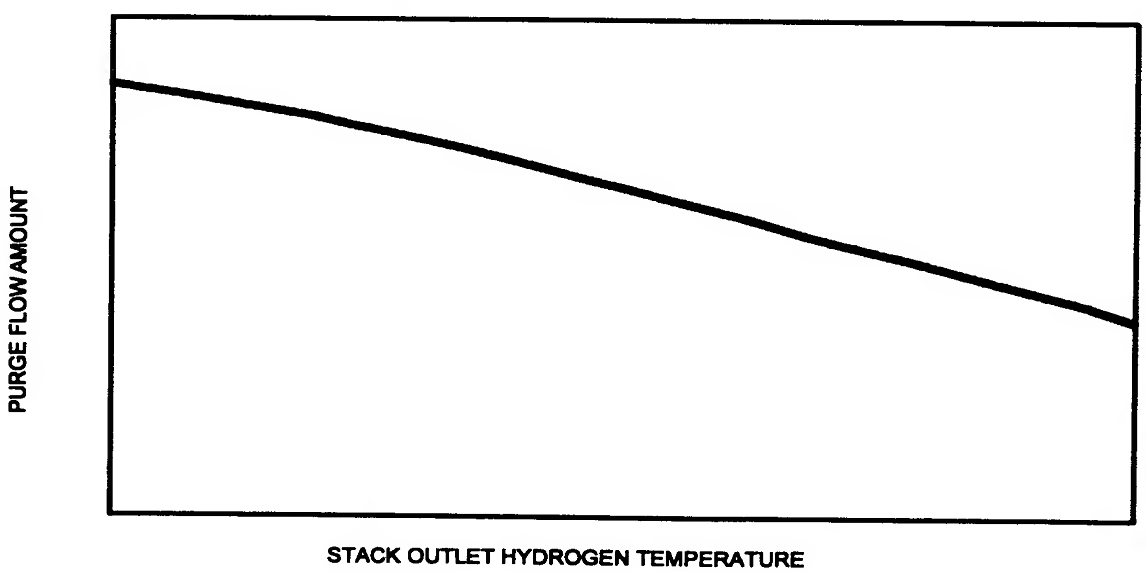
【図5】

【FIG 5.】

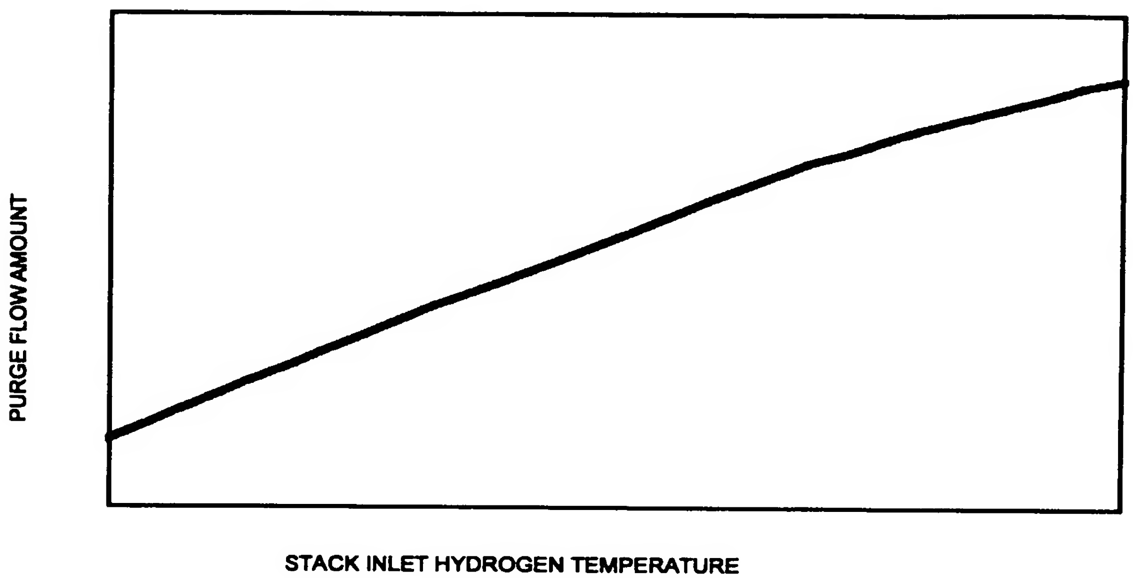


【図6】

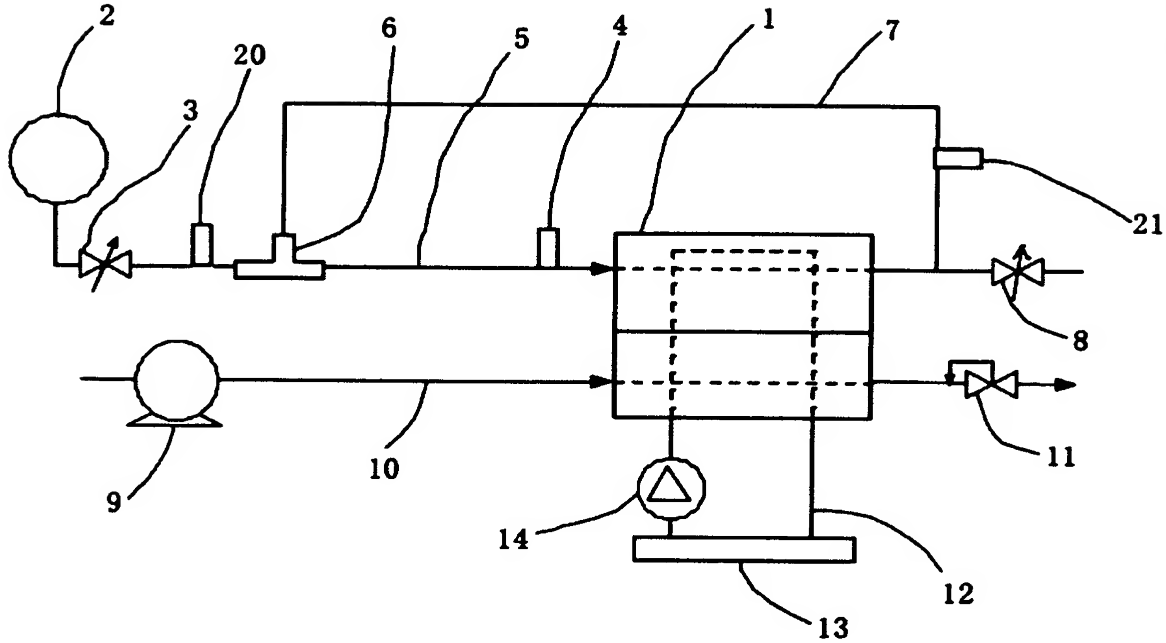
【FIG 6.】



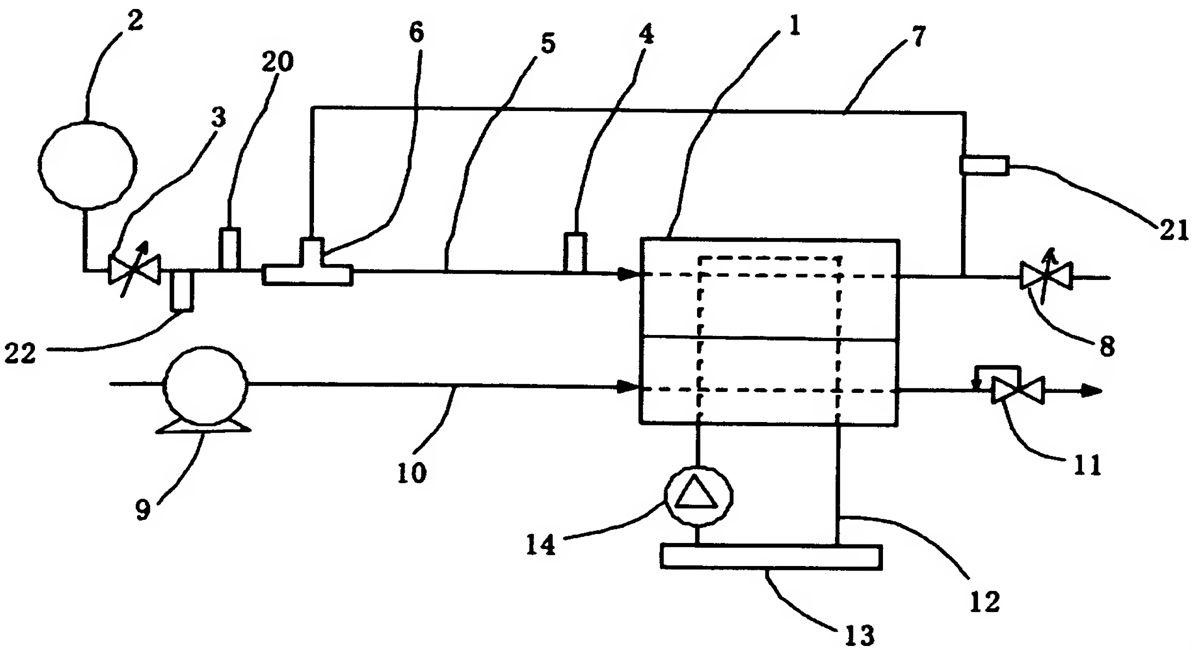
【図7】 【FIG 7.】



【図8】 【FIG 8.】



【図9】 【FIG 9.】



【図10】

【FIG 10.】

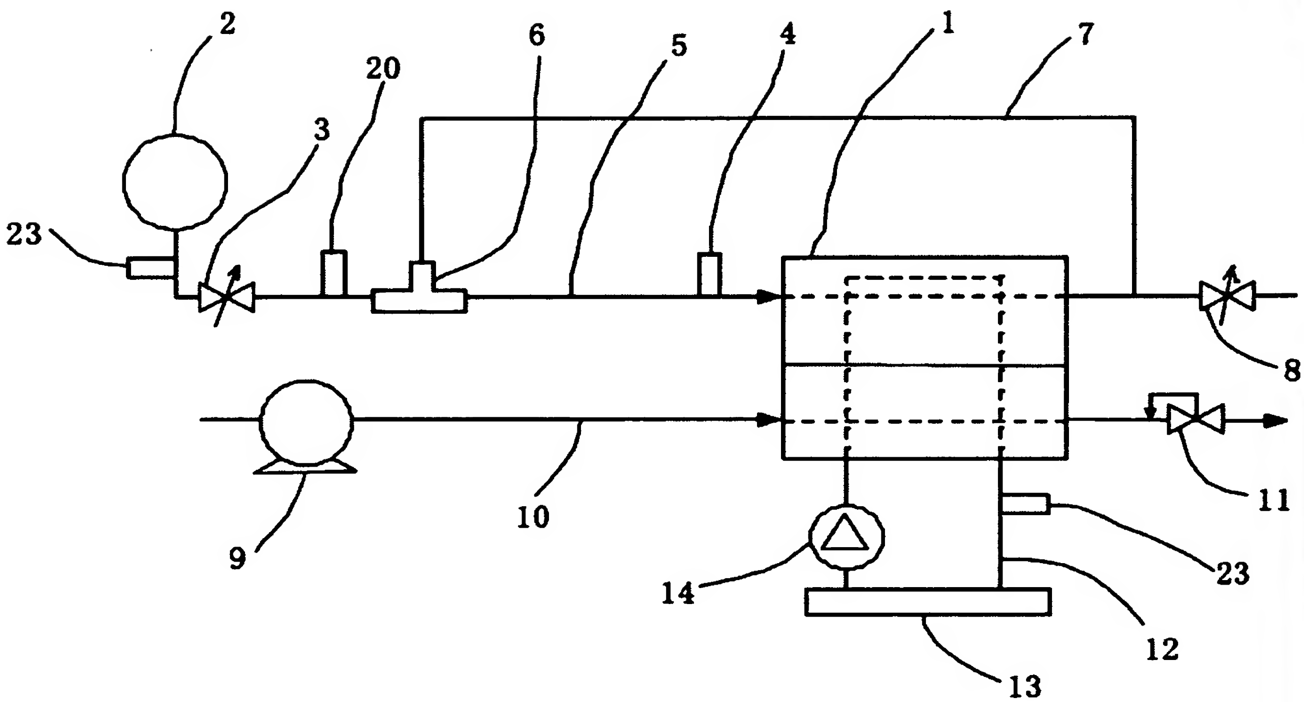


EXHIBIT II

明細書案作成用紙（総研版）　　Form1999/8/27

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相談番号

【発明の名称】燃料電池システム

【特許請求の範囲】

【請求項１】

電解質膜をはさんで燃料極と酸化剤極が対設された燃料電池と、
燃料電池に酸化剤ガス、燃料ガスを供給する、ガス供給手段と、
燃料電池から排出される余剰燃料ガスを燃料電池入口に戻す再循環手段と、
燃料電池の燃料排出､供給通路間を連結する再循環通路から､燃料ガスを排出する通路と、
上記排出通路中に可変絞り弁と、
前記可変絞り弁開度を直接または間接的に検知する手段と、
水素系内の窒素濃度を直接または間接的に検知する手段とを有し、
水素系内の窒素濃度を略一定に保つように、上記可変絞り弁開度を制御することを特徴とする燃料電池システム。

【請求項２】

前記可変絞り弁の通過流量を直接または間接的に求める手段を有し、
上記流量が､運転条件と可変絞り開度に応じて定める所定値よりも多い場合は､上記可変絞り開度を絞り、少ない場合は開けることを特徴とする、前記請求項１記載の燃料電池システム。

【請求項３】

前記所定値が、上記可変絞り弁の開度が大きいほど大きくすることを特徴とする、前記請求項２記載の燃料電池システム。

【請求項４】

前記可変絞り弁を通過するガス温度を直接または間接的に検知する手段を有し、
上記所定値を、ガス温度が高い方が少なくすることを特徴とする、前記請求項２記載の燃料電池システム。

【請求項５】

燃料通路内の燃料ガス圧力を直接または間接的に検知する手段を有し、
上記所定値を、ガス圧力が低い方が少なくすることを特徴とする、前記請求項２記載の燃

料電池システム。

【請求項６】
燃料電池システムへの燃料ガス供給量を、直接または間接的に検知する手段と、
燃料電池システムで消費される燃料ガスのうち、上記可変絞り弁から排出される以外の消費量を直接または間接的に検知する手段とを有し、
上記供給量と消費量との差から、可変絞り弁通過流量を求めることを特徴とする、前記請求項２～５記載の燃料電池システム。

【請求項７】
前記燃料ガスの再循環手段としてイジェクタと、
イジェクタへの燃料ガス供給圧、または供給圧とイジェクタ吐出圧とを検知する手段とを有し、
上記燃料ガス供給圧または供給圧と吐出圧とから、燃料電池システムへの供給燃料ガス流量を算出することを特徴とする、前記請求項６記載の燃料電池システム。

【請求項８】
前記イジェクタの上流の燃料ガス温度を検知する手段を有し、
上記燃料ガス供給圧または供給圧と吐出圧と、イジェクタ上流燃料ガス温度とから、燃料電池システムへの供給燃料ガス流量を算出することを特徴とする、前記請求項７記載の燃料電池システム。

【請求項９】
燃料電池システムに燃料ガスを供給する通路に、可変絞り弁と、
上記可変絞り弁の開度を直接または間接的に検知する手段と、
上記可変絞り弁の上流圧、または上下流圧を検知する手段とを有し、
上記可変絞り弁開度と、可変絞り弁上流圧または上下流圧とから、燃料電池システムへの供給燃料ガス流量を算出することを特徴とする、前記請求項６記載の燃料電池システム。

【請求項１０】
前記可変絞り弁の上流の燃料ガス温度を検知する手段を有し、
上記可変絞り弁開度と、可変絞り弁上流圧または上下流圧と、可変絞り弁上流燃料ガス温度とから、燃料電池システムへの供給燃料ガス流量を算出することを特徴とする、前記請求項９記載の燃料電池システム。

【請求項１１】
燃料電池の出力電流を検知する手段を有し、
出力電流から燃料ガス消費量を算出することを特徴とする、前記請求項６記載の燃料電池システム。

【請求項１２】
燃料電池の出力電流を検知する手段と、
燃料電池の入口または出口の燃料ガス圧力を検知する手段と、
上記圧力の時間変化を検知する手段とを有し、
上記出力電流と、燃料ガス圧力の時間変化とから、燃料ガス消費量を算出することを特徴とする、前記請求項６記載の燃料電池システム。

【従来の技術】

例えば、燃料電池システムとして、特開 2001-266922 に開示されているものがある。
一般に、水素を燃料として用いる固体高分子型燃料電池では、燃料電池スタックで消費するよりも多い水素を供給することにより、安定した発電が可能となる。
本従来例では、イジェクタを用いて燃料電池スタックから排出された余剰水素を、スタック入口側に循環させることにより、余剰水素を捨てることなく消費するより多い水素をスタックに供給し、高効率なシステムを構築している。

【発明が解決しようとする課題】

しかしながら、酸化剤として空気を用いる場合、スタックの膜を通して、空気中の窒素がカソードからアノードに拡散するため、水素中の窒素濃度が増加する。
窒素濃度の増加は、水素分圧の低下を引き起こし、発電効率を悪化させるばかりでなく、イジェクタの循環量の低下により、安定した発電が維持できなくなるという問題がある。
このような問題に対処するためには、水素循環路中から循環水素を大気に放出するパージ弁を設け、パージ弁を定期的に開放して水素とともに水素系内の窒素を排出することが考えられる。しかし、パージ操作は窒素と同時に水素も排出されるため、燃料電池システムの効率が悪化する。
効率悪化を抑制するための、最適なパージ方法に関しては、公開されていない。

本発明は、上記のような従来技術の問題点を解決するためになされたものであり、その目的は、水素系内に拡散してきた窒素を排出するとともに、同時に排出される水素量を最小限に抑制し､燃料電池システムの効率を改善することである。

【発明の効果】

本発明は、電解質膜をはさんで燃料極と酸化剤極が対設された燃料電池と、燃料電池に酸化剤ガス、燃料ガスを供給するガス供給手段と、燃料電池から排出される余剰燃料ガスを燃料電池入口に戻す再循環手段と、燃料電池の燃料排出、供給通路間を連結する再循環通路から、燃料ガスを排出する通路と、上記排出通路中に可変絞り弁と、前記可変絞り弁開度を直接または間接的に検知する手段とを有する燃料電池システムにおいて、以下のような技術的特徴を有する。

請求項１の発明によれば､水素系内の窒素濃度を直接または間接的に検知する手段を有し、水素系内の窒素濃度を略一定に保つように、上記可変絞り弁開度を制御することにより、排出水素量を抑制し効率の高い燃料電池システムを提供可能となった。

請求項２の発明によれば、前記可変絞り弁の通過流量を直接または間接的に求める手段を有し、上記流量が､運転条件と可変絞り開度に応じて定める所定値よりも多い場合は、上記可変絞り開度を絞り、少ない場合は開けることにより、排出水素量を抑制し効率の高い燃料電池システムを提供可能となった。

請求項３の発明によれば、前記所定値が、上記可変絞り弁の開度が大きいほど大きくすることにより、排出水素量を抑制し効率の高い燃料電池システムを提供可能となった。

請求項４の発明によれば、前記可変絞り弁を通過するガス温度を直接または間接的に検知する手段を有し、上記所定値を、ガス温度が高い方が少なくすることにより、排出水素量を抑制し効率の高い燃料電池システムを提供可能となった。

請求項５の発明によれば、燃料通路内の燃料ガス圧力を直接または間接的に検知する手段を有し､上記所定値を、ガス圧力が低い方が少なくすることにより､排出水素量を抑制し効率の高い燃料電池システムを提供可能となった。

請求項６の発明によれば、燃料電池システムへの燃料ガス供給量を、直接または間接的に検知する手段と、燃料電池システムで消費される燃料ガスのうち、上記可変絞り弁から排出される以外の消費量を直接または間接的に検知する手段とを有し、上記供給量と消費量との差から、可変絞り弁通過流量を求めることにより、排出水素量を抑制し効率の高い燃料電池システムを提供可能となった。

請求項７の発明によれば、前記燃料ガスの再循環手段としてイジェクタと、イジェクタへの燃料ガス供給圧、または供給圧とイジェクタ吐出圧とを検知する手段とを有し、上記燃料ガス供給圧または供給圧と吐出圧とから、燃料電池システムへの供給燃料ガス流量を算出することにより､排出水素量を抑制し効率の高い燃料電池システムを提供可能となった。

請求項８の発明によれば、前記イジェクタの上流の燃料ガス温度を検知する手段を有し、上記燃料ガス供給圧または供給圧と吐出圧と、イジェクタ上流燃料ガス温度とから、燃料電池システムへの供給燃料ガス流量を算出することにより、排出水素量を抑制し効率の高い燃料電池システムを提供可能となった。

請求項９の発明によれば､燃料電池システムに燃料ガスを供給する通路に､可変絞り弁と、上記可変絞り弁の開度を直接または間接的に検知する手段と、上記可変絞り弁の上流圧、または上下流圧を検知する手段とを有し、上記可変絞り弁開度と、可変絞り弁上流圧また

は上下流圧とから、燃料電池システムへの供給燃料ガス流量を算出することにより、排出水素量を抑制し効率の高い燃料電池システムを提供可能となった。

請求項１０の発明によれば､前記可変絞り弁の上流の燃料ガス温度を検知する手段を有し、上記可変絞り弁開度と、可変絞り弁上流圧または上下流圧と、可変絞り弁上流燃料ガス温度とから、燃料電池システムへの供給燃料ガス流量を算出することにより、排出水素量を抑制し効率の高い燃料電池システムを提供可能となった。

請求項１１の発明によれば、燃料電池の出力電流を検知する手段を有し、出力電流から燃料ガス消費量を算出することにより、排出水素量を抑制し効率の高い燃料電池システムを提供可能となった。

請求項１２の発明によれば、燃料電池の出力電流を検知する手段と、
燃料電池の入口または出口の燃料ガス圧力を検知する手段と、
上記圧力の時間変化を検知する手段とを有し、
上記出力電流と､燃料ガス圧力の時間変化とから､燃料ガス消費量を算出することにより、排出水素量を抑制し効率の高い燃料電池システムを提供可能となった。

【実施例】

以下、本発明の実施の形態を、図面に従って説明する。
図１に本発明の燃料電池システムを示す。１は固体高分子電解質膜を挟んで酸化剤極と燃料極を対設した燃料電池構造体をセパレータで挟持し、複数これを積層した燃料電池スタックである。燃料としては水素、酸化剤としては空気を用いる。
水素タンク２の水素ガスは、可変絞り弁３を介してスタックに供給される。可変絞り弁３は､通常運転時は､圧力センサ４で検知したスタックへの水素供給圧が適正になるように、図示しないコントローラで制御される。
可変絞り弁３とスタック１の間の水素配管５には、イジェクタ６が設けられる。スタックから排出される余剰水素は、水素戻り配管７からイジェクタの吸入口に戻され、イジェクタで水素を循環させることにより、スタックの安定した発電を維持するとともに、反応効率を上げている。
可変絞り弁８は、水素系内の空気極から拡散してきた窒素の濃度が略一定となるように、窒素を外部に排出するためのパージ弁であるとともに、内部に開度センサを持ち、図示しないコントローラにより、その開度が調整される。可変絞り弁８の制御方法に関しては後述する。

なお、コンプレッサ９から、供給路 10 を通してスタックに供給された空気は、空気調圧弁として作動させる可変絞り弁 11 を通して排出される。
またスタックを冷却するための冷却水通路12には､放熱のためラジエータ 13 が設けられ、

冷却水ポンプ14で循環する。

次に、図2のフローチャートに基いて、作動を説明する。
まず、S1で現在のパージ流量、すなわち可変絞り弁8の通過流量が所定値以上か判定し、所定値以上の場合はS2でパージ弁開度を下げ、所定値以下であればS3でパージ弁開度を上げるようにした。

次に、効果について説明する。
図3には、水素温度、圧力が一定の場合に関して、水素系内の窒素濃度とイジェクタの循環水素流量との関係を示す。窒素濃度が上がると、水素により大きな分子量の窒素が混合すること、また水素分圧が下がることにより、イジェクタ循環水素流量が低下していく。そこで、パージにより、水素系内の窒素濃度が所定値よりも高くならないようにする必要が出てくる。
例えば、スタックを安定して運転できる最小のイジェクタ循環量をQrとすると、循環量がQrを下回らないように、水素系内の窒素濃度をRn以下にしなければいけないのである。
ここで、水素系内の窒素を排出する場合、水素も同時に排出されてしまうため、全体としての燃料電池システムの効率は低下することになる。ここで、この効率悪化を最小限とするためには、パージガス中の水素濃度をできるだけ低くする、すなわち、パージガス中の窒素濃度をできるだけ高くすることが有効である。言い換えると、パージガス中の窒素濃度が常にRnとなるように、パージ弁開度を調整することにより、排出水素を最小限にとどめることが可能なのである。

図4には、パージ弁開度、水素温度、圧力が一定の場合に関して、水素系内の窒素濃度とパージ流量の関係を示す。窒素濃度の減少に伴い、パージ流量は増加する。
図5には、水素温度、圧力、水素系内窒素濃度が一定の場合に関して、パージ弁開度とパージ流量の関係を示す。パージ弁開度を上げると、パージ流量は増加する。

図6には、等窒素濃度、圧力、パージ弁開度での、スタック出口水素温度に対するパージ流量を示す。スタック出口、すなわちパージ弁入口は、固体高分子型燃料電池スタックの場合は、水蒸気が飽和した、あるいは飽和に近い状態となっている。温度が上がると、飽和水蒸気圧が上昇し、スタック出口ガスの平均分子量が増加することにより、パージ流量が減少するのである。

図7には、等窒素濃度、温度、パージ弁開度での、スタック入口水素圧力に対するパージ流量を示す。圧力が低いほど、等窒素濃度でのパージ流量は減少する。

以上より、パージ流量、パージ弁開度、水素の温度、圧力がわかれば、水素系内の窒素濃度がわかることになる。

次に、パージ流量の検知方法に関して説明する。

本実施例では、システムに供給される水素流量と、パージ以外で消費される水素流量を求め、その差からパージ水素流量を求めるようにした。
まず、システムに供給される水素流量の求め方について説明する。
一般に、絞りを通過する流量は、チョーク状態では絞りの上流圧と温度、非チョーク状態では絞りの上下流圧と上流温度から算出することができる。
本実施例では、イジェクタのノズルが絞りとなるため、これを用いて供給水素流量を求めるようにした。
今、水素の供給温度があまり変化しない場合を考える。図８に示すように、イジェクタ上流に圧力センサ 20 を設ける。イジェクタ下流圧は、スタック入口水素圧とほぼ等しいので、圧力センサ 4 で検知できる。よって、イジェクタの上下流圧が検知できるので、システムへの供給水素流量が算出できるのである。
また、供給水素温度の変化が大きい場合は、図９に示すように、イジェクタ上流に温度センサ 22 を設けることにより、より高精度で供給水素流量を算出することができる。

次に、パージ以外の消費水素流量の求め方について説明する。
スタックでの消費水素量は、スタックの出力電流に比例する。従って、図示しない電流計を設けてスタック出力電流を検知することにより、パージ以外の消費水素流量が算出できるのである。

なお、21 はパージ弁入口部近傍の水素温度を検知するためのセンサであり、前述した温度により水蒸気圧が変わり、パージ流量が変化することに対応する。

上述してきた特性から、パージ弁開度、パージ流量、水素圧、水素温度が検知できる。
また、その時のパージ弁開度、水素圧、水素温度で、窒素濃度が所定の値の場合のパージ流量を算出することができる。この算出したパージ流量を、図２のフローチャートの所定値と置き、検知したパージ流量と比較するのである。
すなわち、本所定値は、パージ弁開度が大きいほど多く、水素温度が高い方が少なく、水素圧が低いほど少なく設定するのである。

以上説明してきたように、本発明により、水素系内の窒素濃度を略一定に制御することが可能となり、窒素濃度過多により発電が不安定になることを防止しつつ、過剰なパージで窒素とともに無駄に水素を排出することを抑制し、安定した運転が可能であるとともに、効率の高い燃料電池システムを提供可能となった。

次に第２の実施例について説明する。
本実施例では、図１０に示すように、水素調圧弁３の上下流に圧力センサ 23、20 を設け、水素調圧弁の上下流圧から水素の供給流量を算出するようにした。
水素調圧弁の開度がわかれば、第一実施例でのイジェクタの上下流圧から流量を求める場合と全く同様に、流量を求めることができる。
すなわち、水素調圧弁３の開度、水素調圧弁の上下流圧から、供給水素流量を算出するの

である。
調圧弁がチョーク状態にある場合は上流圧のみ、非チョーク状態にある場合は上下流圧から流量を算出するのは、第一実施例と同様である。
また、本実施例では、水素温度の検知には、温度センサ 23 で検知したスタック冷却水温度を用いるようにした。スタック内では、水素と冷却水は熱交換を行うため、冷却水温度で水素温度を推測することが可能であり、また、水素ガス温度よりも水温の方が応答良く検知できるため、例えば負荷変動が早く温度の変化速度が速い場合は、直接水素温度を測定するよりも精度が向上する。
なお、第一実施例と同様、水素調圧弁 3 に供給される水素の温度が変化する場合は、調圧弁上流の水素温度を検知するセンサを設けて、より高精度で供給水素流量を算出することができる。

次に、第 3 の実施例について説明する。本実施例の構成は、第一、または第二実施例と同様であり、消費水素流量の算出方法に改良を加えたものである。
例えば、車両用の燃料電池システム等で、負荷変動の速度が速く、また、負荷によってスタックに供給する水素圧を変えるような場合がある。
このような場合､例えば圧を上げる場合は､スタックでの発電で消費されるよりも多量の、逆に圧を下げる場合は少量の水素を供給することになり、スタックの発電による消費量だけしか考慮しない場合は、過渡時のパージ流量を正確に算出できなくなる。
ここで、水素系の圧力を上げる、または下げるために、水素系に供給する水素量は、圧力の変化代に対して比例する。すなわち、
　供給水素量＝スタック発電消費量＋定数×圧力変化量
となる。ここで、上記定数は、燃料電池システムの水素系容積によって定まる。
よって、圧力センサ 4 で圧力の変化率を求めることにより、過渡時も含めて水素供給量が算出可能となる。
以上説明してきたように、本実施例により、水素圧力が変化するような場合でも、正確に水素供給量を算出可能となり、より高精度にパージ流量が算出できるため、水素系内の窒素濃度をより正確に制御できるようになった。

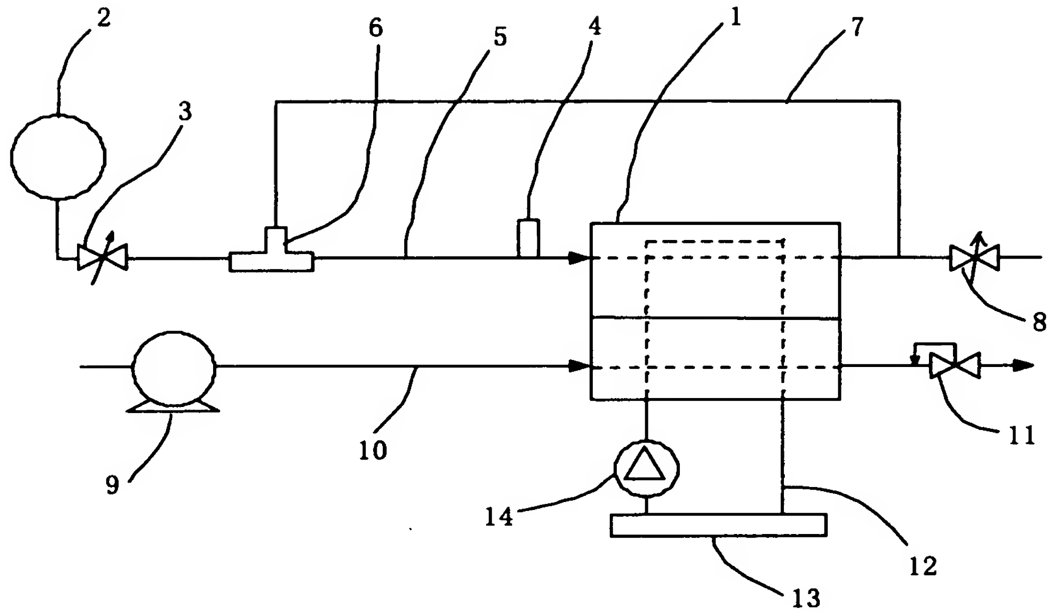
なお、以上全て、水素を循環させるためにイジェクタを用いた場合について説明してきたが、例えばポンプやブロアを用いて循環させる場合にも、本発明は適用できる。
ポンプやブロアを用いた場合でも、イジェクタと同様、窒素濃度が上昇すると水素分圧が低下するため、スタックへの水素供給量が不足するようになる。
ポンプやブロアを用いた場合も、上記第二実施例と同様に、水素調圧弁の開度と上下流圧から水素供給量を算出し、全く同様にパージを閉じる最適時期を求めることができるのである。

また、水素圧力の検知位置を水素のスタック入口として説明してきたが、出口側でも構わないことはいうまでもない。スタックの水素圧損が大きい場合は、出口側圧力を用いた方が精度が上がる。

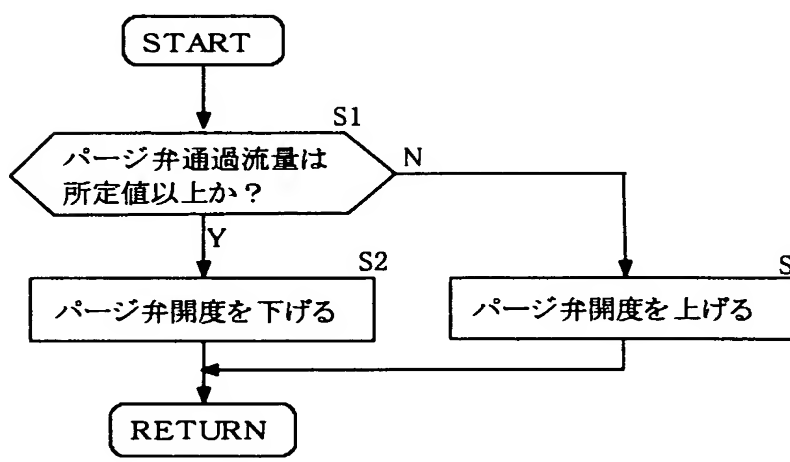
図面の簡単な説明

図１：本発明の基本構成を示す図である。
図２：本発明の基本作動の概要を示すフローチャートである。
図３：水素系内窒素濃度に対するイジェクタ循環水素流量を現す図である。
図４：水素系内窒素濃度に対するパージ水素流量を現す図である。
図５：パージ弁開度に対するパージ流量を現す図である。
図６：スタック出口水素温度に対するパージ流量を現す図である。
図７：スタック入口水素圧力に対するパージ流量を現す図である。
図８：本発明の第一実施例の構成を示す図である。
図９：本発明の第一実施例の構成を示す図である。
図１０：本発明の第二実施例の構成を示す図である。

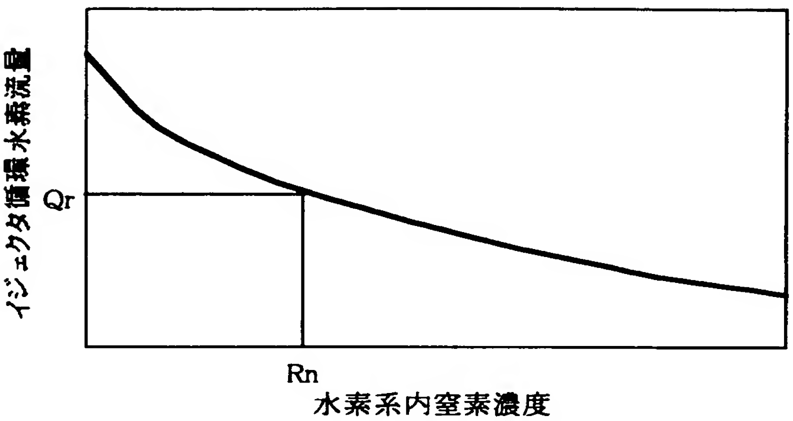
【図1】


2
6
5
4
1
7
3
8
11
9
10
14
12
13

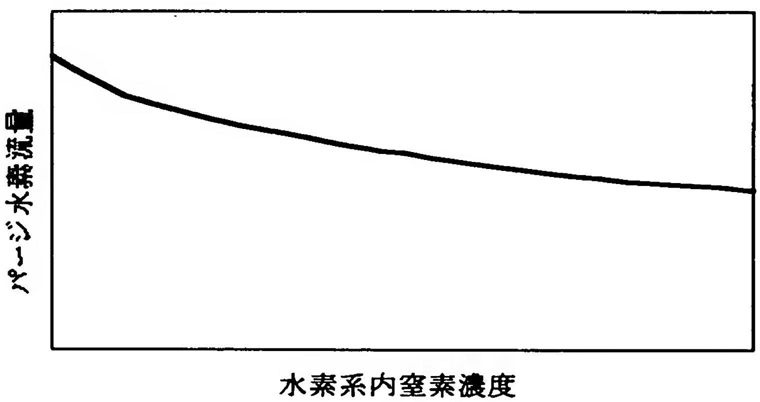
【図2】


START
S1
パージ弁通過流量は
所定値以上か？
N
Y
S2
パージ弁開度を下げる
S3
パージ弁開度を上げる
RETURN

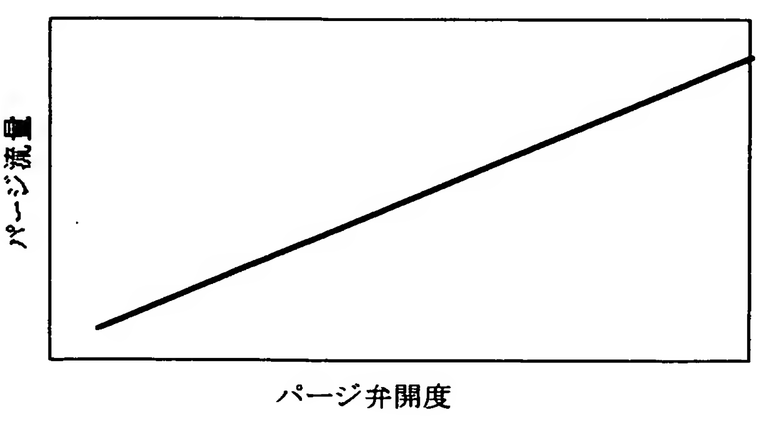
【図3】



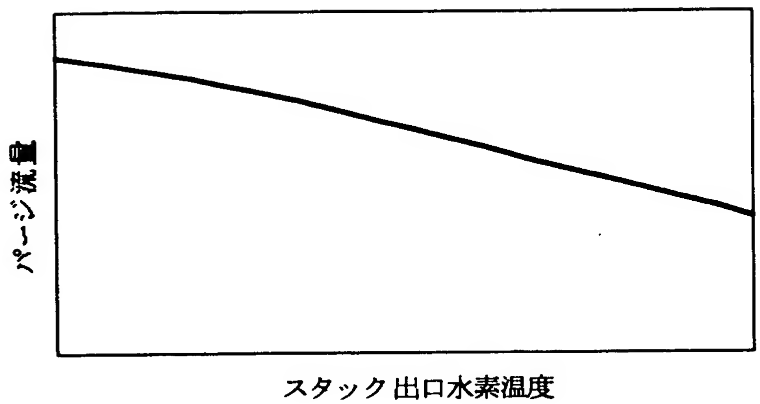
【図4】



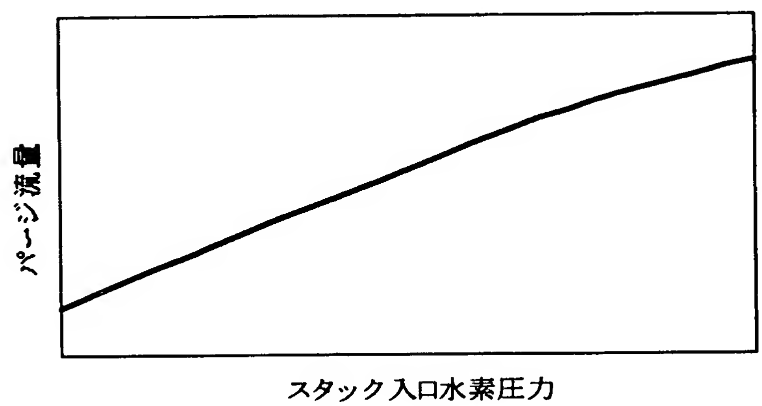
【図5】



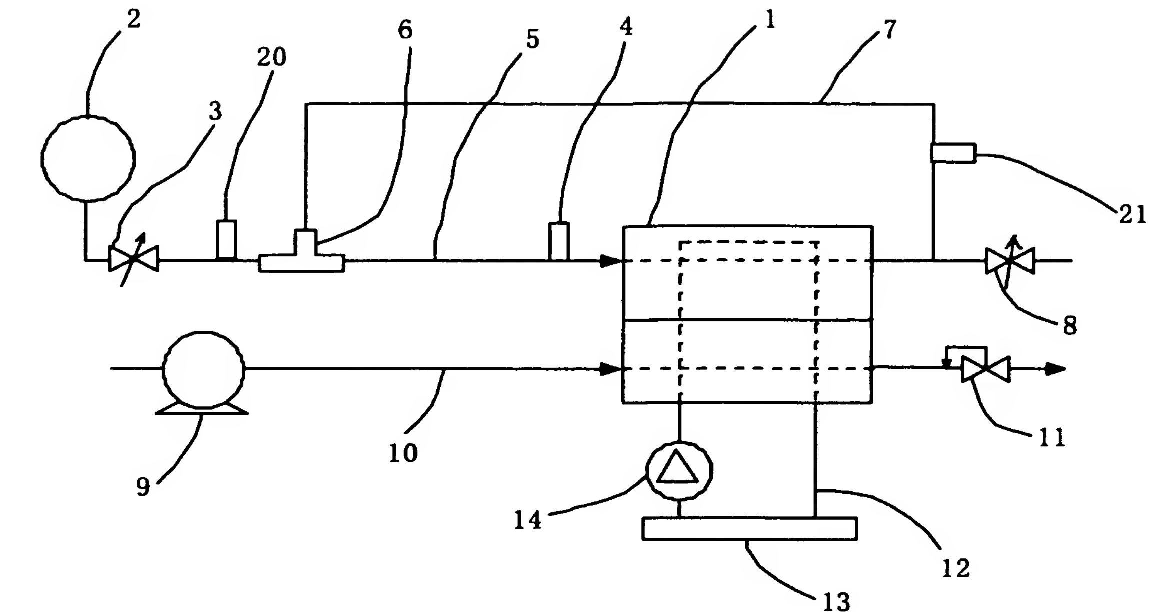
【図6】



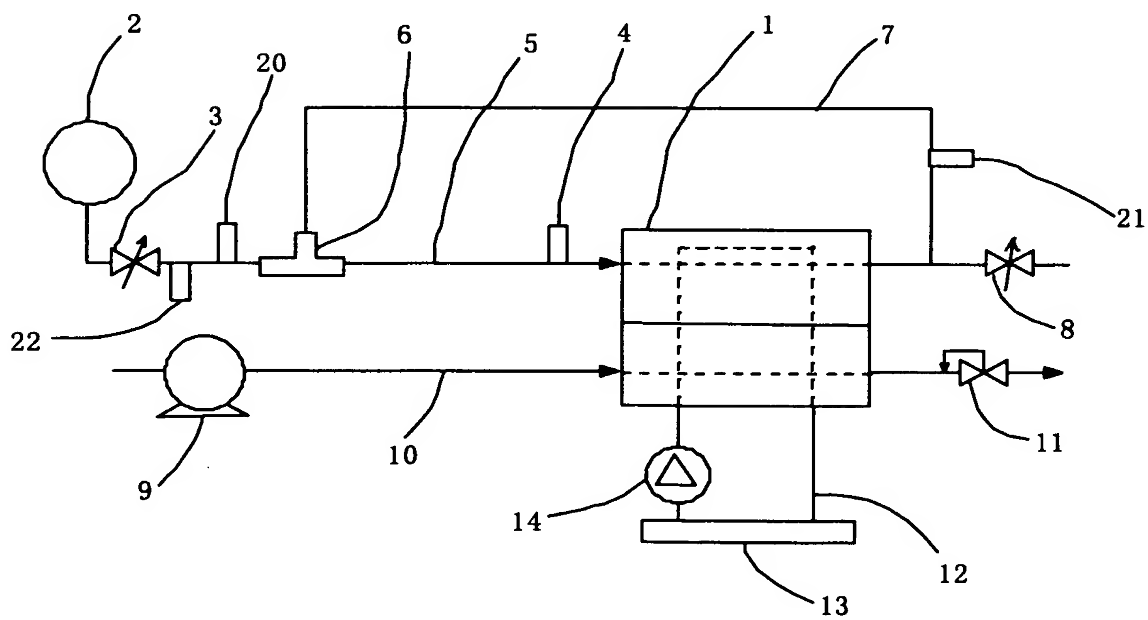
【図7】



【図8】



【図9】



【図10】